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Water Cities
Can We Climate-Proof the Coast?

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Rising sea level and more intense downpours are driving more frequent nuisance flooding events in Charleston and many other U.S. coastal cities.

PHOTO/GRACE BEAHM

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Coastal Science
Serving South Carolina

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FLOOD-PRONE. A man rescued a bus driver from a stranded shuttle in downtown Charleston during a heavy downpour that struck during an unusually high tide.

PHOTO/GRACE BEAHM

Water Cities *Can We Climate-Proof the Coast?*

by John H. Tibbetts

The water has nowhere to go. When an intense downpour hits the Charleston peninsula at a high tide, much of the city's storm-drainage system has already reached saturation. Its pipes, ditches, and outlets are filled up with brackish tidewater. In worst cases, floods spill over curbs and sidewalks, motorists stall in murky water that laps across their hoods, and kayakers paddle in the popular City Market and Market Street in the heart of the historic district. Streets have to be closed, and many businesses are disrupted.

It's a 300-year-old problem. The Charleston peninsula was a low-elevation place when European settlers

arrived. City officials and residents dumped trash and waste in salt marshes and tidal creeks. Later, low places were filled in to build houses and businesses, and some salt marshes and creeks were targeted for destruction because they were associated with disease outbreaks.

Architect Robert Mills in his 1826 *Statistics of South Carolina* praised Charleston's many "industrious enterprising individuals, [who] by draining marshes, and filling up creeks, advanced their private interests, and contributed to the growing salubrity of the town."

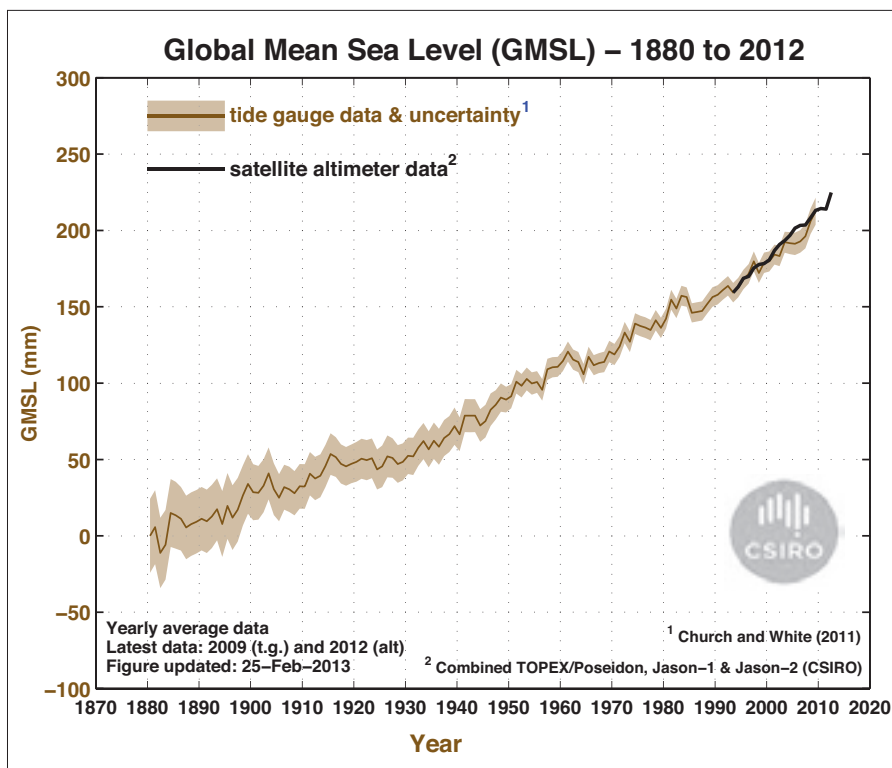
Between 1804 and 1807, a tidal watercourse named Governor's Creek

was filled in to build what is now the flood-prone City Market and Market Street so favored by urban kayakers.

Historic maps show when and where development advanced across marshlands and creeks. The footprint of the peninsula today is about 50% fill, and the fill sites are still the lowest spots in the city and experience the most flooding, according to Laura Cabiness, director of the city's Department of Public Service.

"They just barely filled the creeks to get them dry," she says, "and all the water wants to make its way to its natural channels."

Now low-elevation neighborhoods, some only four or five feet



Satellite data show that global sea-level rise has accelerated since the early 1990s.
GRAPHIC/NEIL WHITE/CSIRO

above sea level, are getting wetter more often for a number of reasons.

Along one stretch of the South Carolina coast, from Charleston and farther points south, the land is sinking—or subsiding—primarily because of natural geological pressures on the region’s continental shelf. The subsidence rate is about five inches per century at the water-level gauge in Charleston Harbor.

Global sea level, meanwhile, has risen eight inches over the past century, but its pace has doubled since the early 1990s because of climate change. Thunderstorms, moreover, are producing more intense downpours in the eastern half of the United States since the 1950s, also because of climate change. Finally, Charleston’s flood-prone neighborhoods, built on loose salt-marsh sediments, are sinking as those sediments and fill compact.

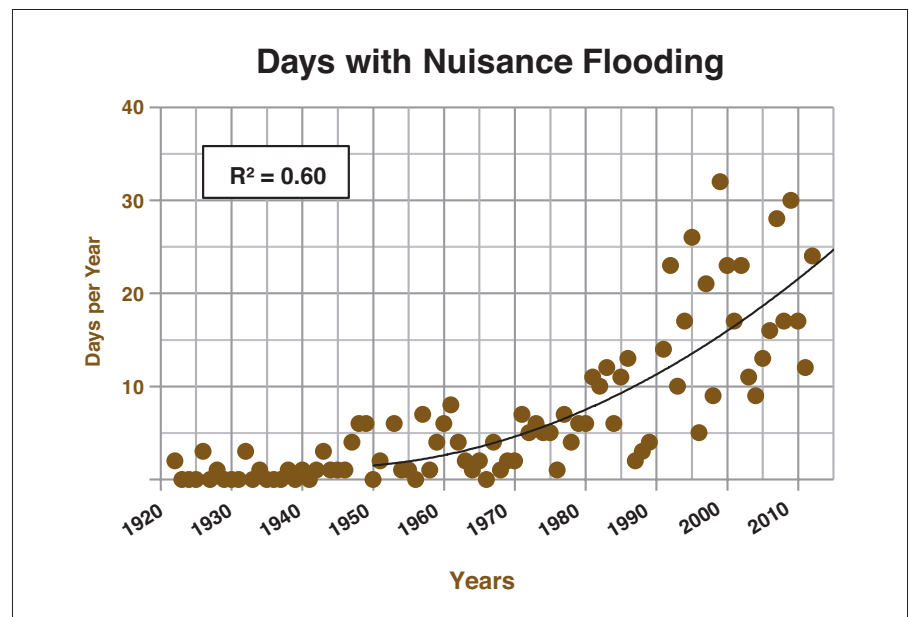
Charleston is one of the U.S. cities most threatened by rising global sea level, according to the 2014 National Climate Assessment produced by 13 federal agencies. Other

cities on the short list are New Orleans, Miami, Tampa, and Virginia Beach. Global sea level could rise by up to 6.6 feet by 2100, according to the assessment.

Charleston is also one of the top seven U.S. cities with frequent “nuisance flooding events,” causing backed-up storm drains and closed roads. From 1957 to 1963, Charleston had an average of 4.6 days per year of nuisance flooding. From 2007 to 2013, that number jumped to 23.3 days per year, an increase of 409%, according to a recent study led by William Sweet, an oceanographer with the National Oceanic and Atmospheric Administration (NOAA). Nuisance coastal flooding is a “sensible indicator” for communities to track as they plan for climate-related sea-level rise, Sweet says.

“A little bit of increased sea-level rise can have an exponential effect in terms of these nuisance tides,” says Sweet. “Any future acceleration of global sea-level rise, which is predicted, is only going to make the time between these nuisance events shorter and their intensity greater. So this problem is not going away, and it’s only going to increase impacts in our communities.”

To reduce flooding of urban streets and buildings, U.S. coastal cities have built “hard” or “gray” flood-control structures (seawalls, bulkheads, rip-rap) and storm-drainage systems (canals,



Charleston’s nuisance flooding has increased dramatically over the decades in concert with rising global sea level.

GRAPHIC/WILLIAM SWEET/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

tunnels, pumping stations).

But now some communities are rethinking that model.

"We need to learn not just how to live *on* the water but live *with* the water," says Skip Stiles, executive director of Wetlands Watch, a non-profit organization based in Norfolk, Virginia.

WATER AND THE DUTCH

To live with the water, some U.S. coastal communities are taking lessons from the Dutch who are world leaders in coastal protection and stormwater management.

Over centuries, the Dutch drained and filled marshes and waterways to create new, dry land, just as Charlestinians did. The Netherlands, with exactly half the square miles of South Carolina, could almost fit into our coastal plain.

About one quarter of Holland's land area is below sea level, but it's home to more than 60% of the total population of 17 million. The country would experience catastrophic flooding without its existing infrastructure of hard dikes, levees, seawalls, and other coast-and-river engineering.

The Dutch don't experience tropical cyclones. But they do endure inland river flooding and ferocious North Sea storms. So the Netherlands incrementally built stronger and stronger flood-protection structures. In a 1953 storm, however, some major dikes failed, and more than 1,800 Dutch died. The Dutch sealed most of their last open estuaries to improve flood protection.

But, by the early 1970s, the Dutch realized that walling off estuaries had caused severe water-quality problems and damaged fisheries. Over centuries, they had lost 90% of their historic wetlands.

They were faced with a dilemma: how could they balance costs and benefits of flood protection against what remained of their country's ecological health?

Protecting lives and property had



ENGINEERED. This massive surge barrier in the Netherlands is one of many similar sea walls that protect the nation's flood-prone estuaries from North Sea storms. PHOTO/DREAMSTIME

to be the highest priority, the Dutch decided. But they began supplementing their hard flood-control and storm-drainage structures with a "living with nature" plan, which perhaps could be more accurately named a "living with engineered nature" plan.

The Dutch have built extensive "soft" or "green" infrastructure as a way to make up for past damage. For instance, they have created or restored barrier islands and beachfronts to buffer high waves and winds. Behind those soft storm barriers, they have restored oyster reefs, wetlands, and forests for multiple functions: filtering and storing water, buffering storm energy, and offering wildlife habitat.

In rural areas, they are planting buffers of vegetation to slow and filter storm runoff. The idea is to capture runoff at sites where vegetation, soils, and beneficial microbes can naturally soak in stormwater and cleanse it. That way, excess rainwater is given a pause as it flows downslope or into groundwater. Stormwater can't run as quickly off impervious surfaces, so it's less likely to cause flash floods and carry contaminants into waterways.

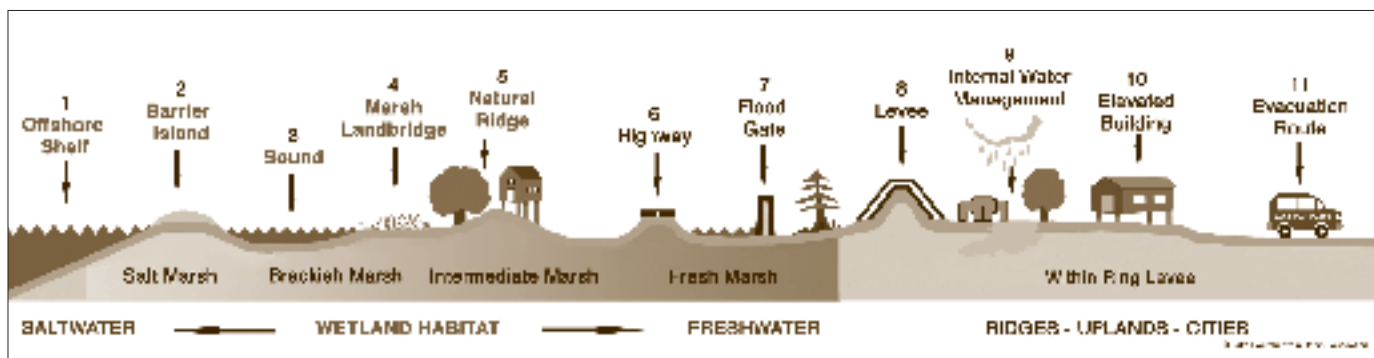
"The Dutch have perfected not having to rely so much on gray

infrastructure," says Dale Morris, an American economist with the Royal Netherlands Embassy in Washington. Morris has been a key player in bringing awareness of Dutch water-management principles to New Orleans. "They've shown that you can increase flood protection with green infrastructure while reducing its cost."

Holland, moreover, has been historically unwilling to retreat from rising water, but that's changing as sea level rises and river flooding becomes more extreme. The Dutch have bought out several farms to create parklands that fill with water during floods.

Americans should also begin thinking about retreat from the water. "It's human nature not to let flooding happen," says Michael Slattery, coastal processes specialist with the S.C. Sea Grant Extension Program and Coastal Carolina University. "We don't just let places flood. But we need to start thinking more realistically about whether we can continue doing that in every location."

The Dutch experience of catastrophic flooding has taught them to be adaptable managers of risk. They continually study flood and sea-level threats, gauge their vulnerabilities,



To preserve Louisiana's coastal marshlands and urban centers, the state's master plan outlines a \$50 billion "multiple-lines-of-defense" system to be completed by 2050.

GRAPHIC/LAKE PONTCHARTRAIN BASIN FOUNDATION

revisit disaster forecasts, and evaluate the most cost-effective tools and approaches to prevent problems. They are planning for a global sea-level rise of 80 centimeters (2.5 feet) by 2100.

By contrast, some policymakers in the United States have resisted considering how high sea level could rise beyond historical rates of the 20th century.

"We need to think with a longer-term perspective, and the Dutch are masters of doing that," says Stan Bronson, executive director of Florida Earth Foundation, a nonprofit organization that runs the U.S.-Netherlands Connection Professional Program for graduate study in water infrastructure and management. "The Dutch have been fighting water for centuries, but they see that the game is changing so fast that the old way of doing things is probably not going to work. In the Netherlands, the discussion is not about whether sea-level rise exists. The discussion is how do we adapt to it and how do we create resilience around it."

But South Carolina may not want to imitate Holland's past mistakes and brace many of its coastlines with seawalls, bulkheads, and other hard erosion-control structures. South Carolina would lose natural coastal features that way. In any case, hard barriers eventually will be overcome by sea-level rise.

"The Dutch are brilliant engineers, and they've figured out a lot of things," says Chester Jackson, a coastal geologist at Georgia Southern Univer-

sity. "But you can't hold the line against rising sea level forever. It's too bad that people have hardened the coast before we have understood the science behind rising sea level."

HARD-AND-SOFT PERIMETER

During the 18th and 19th centuries, seaports in North America filled in their complex, permeable shorelines of salt marshes and tidal creeks. In doing so, they created the artificially hard, straight borders between land and sea that we see today along urbanized coastlines.

Charleston, for instance, filled in creeks and salt marshes to build out wharves and piers, which allowed access to deeper water for larger ocean-going vessels. The term "waterfront" was coined to describe a clearly defined space found at every seaport.

As port cities simplified, straightened, and hardened their coasts, they grew rapidly in population. Municipal officials and developers further filled and drained low areas in efforts to relieve overcrowding and to control the "bad air" and diseases that people thought came from marshlands.

Most of the city of Boston was built on filled-in salt marshes and tidal flats. In New York City, much of Queens and significant parts of the Bronx and Brooklyn expanded on salt marshes as well. Manhattan was widened, and its southern tip was extended. In New Jersey, numerous towns near the Hackensack

Meadowlands were built on fill material on salt marshes.

In the 1970s, wetland destruction slowed in the United States and Europe because of ecological concerns. Now rising sea level and storm surges are threatening many urban centers along intensively developed estuaries and deltas where marshes were lost. Hurricane Sandy devastated low-elevation areas in New York and New Jersey that had once been salt marsh or open water.

Wetland destruction, though, continues in some regions. New Orleans was once blessed with vast natural buffers between the city and Gulf storms that hit the coast. But over the past 80 years, South Louisiana lost about 2,000 square miles of marshy coast to rising global sea level, levees on the Mississippi River, and extensive canal dredging for oil and gas industries. South Louisiana is the fastest subsiding delta in the world, losing a football-field-size of marshland every 48 minutes.

In 2005, Hurricane Katrina's surge roared across open water and up canals to overcome flood protections, swamping stretches of the New Orleans metro area, scientists say.

Soon after Hurricane Katrina, the Netherlands government offered to help New Orleans and South Louisiana design and build improved coastal protections. U.S.-Netherlands collaborations informed Louisiana's 2007 Coastal Master Plan, which called for a "multiple-lines-of-defense"

model for the region. It would be Louisiana's first blueprint of how the state would use federal and state restoration funds.

Dutch engineers, landscape architects, city planners, and soils/hydrology experts and their American counterparts have continued collaborations in South Louisiana.

An updated 2012 Coastal Master Plan filled in many details. Barrier islands would be restored along the Gulf Coast to blunt hurricane energy; one has been completed at the Grand Isle Barrier Island. At the next line of defense, restored salt marshes would buffer storm height and waves. The next lines of defense would consist of restored oyster reefs, rebuilt natural ridges, and freshwater marshes. Miles of new or rebuilt levees and floodwalls have already been constructed to protect the New Orleans area. Inside floodwalls, homes and other structures would be elevated.

If all of the plan's projects were completed, it would cost up to \$50 billion (in 2012 dollars) over 50 years, to be supported by a variety of sources, including state shares from oil-and-gas revenues and fines and settlements with companies related to the Deepwater Horizon oil spill.

Like the Netherlands, South Louisiana can't be returned to nature. "Once it's a managed system," says Frank Newell, president of Newell Engineering in Metairie, Louisiana, "it's a managed system." In South Louisiana, engineers will have to manage water flows and sediments in perpetuity to prevent the region from disappearing.

Could the South Carolina coast someday be managed on a similarly aggressive scale? Today, most of South Carolina's developed beaches are already being renourished with sand to protect private property behind them. South Carolina, moreover, is restoring many oyster reefs, and the state might follow Louisiana's model and attempt to restore protective salt marshes as they start to drown. The Dutch model shows that coastal

development can be protected for decades by a combination of hard-and-soft infrastructure, but the rising costs and dangers of holding back the sea will only increase as global sea level rises.

HARD-AND-SOFT INTERIOR

It's raining harder than it used to—in the eastern half of the United States at least.

Since the mid-20th century, the amount of precipitation falling in very heavy rainstorms in one-hour increments is way up—by 71% in the U.S. Northeast, 37% in the Midwest, and 27% percent in the Southeast, according to the 2014 National Climate Assessment.

"We are seeing an unexpected intensity of storms with more water falling in a shorter time," says Carl Simmons, Charleston County's building official. People are also building homes in more flood-prone locations, he adds. "There isn't as much good [high-elevation] land to build on anymore. Those areas are already developed. So people are moving down right beside rivers" in low-elevation places.

Many cities around the country are building underground tunnels to hold excess rainwater and using

energy-intensive turbines to pump it into nearby waterways. But now many leaders of the New Orleans metro area want to keep more rainwater in the city.

In September 2013, an economic-development group called Greater New Orleans, Inc. released a water plan for the metro area. The Greater New Orleans Water Plan, created by Waggonner and Ball Architects with Dutch and U.S. consultants, envisions New Orleans as a "water city" like Amsterdam or Rotterdam in the Netherlands.

The plan calls for broadening the principles of "multiple-lines-of-defense" to include green infrastructure in urban water management.

For decades, New Orleans has used massive turbines to pump its excess rainwater into Lake Pontchartrain and other waterways.

"We have relied on giant pumps, a technology that is so powerful that we fell in love with it," says David Waggonner, a principal with Waggonner and Ball Architects.

The new plan calls for retrofitting the metro's parks, canals, and other public spaces to soak up far more stormwater. The plan promotes the use of rainwater as a resource and an amenity rather than as a nuisance.

"You keep the water where it falls



BEAUTY AND FUNCTION. A New Orleans "water plan" calls for rehabilitating the metro area's canals into attractive tree-lined amenities that would provide more stormwater storage and filtration.

IMAGE/WAGGONNER AND BALL ARCHITECTS



WATER PLANNER. *David Waggoner*
PHOTO/JOHN H. TIBBETTS/S.C. SEA GRANT
CONSORTIUM

and store it and pump it only when you have to," says Waggoner.

The city is crisscrossed with grim-looking cement canals. The new plan calls for restoring canals into attractive tree-lined amenities that could raise adjacent property values. The canals would be redesigned to allow more stormwater storage and filtration. Similarly, redesigned city streets and utility rights-of-way could capture more rainfall with pervious pavements, bioswales, rain gardens, urban wetlands, pocket parks, and linear greenways linked to storm basins.

The plan, which cost \$2.5 million to draft, would have a total price tag of \$6.2 billion if completed. Local leaders are raising private funds to match support from the U.S. Department of Housing and Urban Development (HUD) and other federal agencies.

Today, the metro area has hundreds of empty lots where homes and businesses were flooded during Katrina and structures were razed. A few sites are already being used as quarter-acre-size rain gardens cooled by new tree plantings.

"The ability to use this unused land for water management is actually a real-estate benefit," says Waggoner.

"The horrible storm created a lot of opportunities for us. In most urban places you can't get [water management] back because there's a shopping center there. But now people in New Orleans neighborhoods want to try something different, and when they do, they see there's less flooding."

COASTAL CITIES LOCK-IN RISK

The Dutch have become exceptionally skilled at preventing floods. Americans, by contrast, have become exceptionally skilled at rebuilding communities following natural disasters. These different skills emerged from different national geographies, terrains, histories, and cultures.

The Dutch realized long ago that major floods are not localized events but occur on a watershed scale. The Dutch have powerful "water boards," which are independent regional government bodies that manage water. Some have histories that go back 800 years. Water boards are democratically elected and have the power to levy taxes. They work closely with regional and national governments, academia, industry, and non-governmental organizations to manage long-term water policy and infrastructure.

The United States, of course, can't focus on one type of disaster in one relatively small geographic area. Americans live in many types of terrain from swamps to mountains, in a variety of climates from deserts to temperate rain forests, and in temperatures varying from arctic cold to subtropical heat. Americans cope with wildfires, droughts, snowstorms, earthquakes, severe thunderstorms, tsunamis, and tornadoes in addition to river flooding and coastal storm surges.

Americans depend largely on local knowledge to address site-specific hazards. Each U.S. locality makes most of the decisions about where and how to build. Americans have a long history of home rule, especially in regard to land use. The federal government, except in special cases, stays out of land-use planning, as do most state

governments.

In 1968, Congress established the National Flood Insurance Program (NFIP) in part to encourage localities to improve their planning with floods in mind.

The program was a historic effort in the United States to reduce the nation's dependence on hard structures to manage flooding. The principle was to live with infrequent inundations and avoid costly damages to structures by raising their elevation, among other measures.

Localities continue to make most development decisions. But the NFIP is based on federal flood-risk mapping. Every five years, the Federal Emergency Management Agency (FEMA) creates maps that designate locations of the nation's 100-year floodplains. Any homeowner with a federally backed mortgage within those floodplains must purchase flood insurance.

Each new and substantially remodeled home must have its first inhabited floor elevated at or above the 100-year flood elevation. Elevating a structure off the ground, then, would allow a 100-year flood event to flow under the building.

The NFIP offers financial incentives for communities that develop non-structural flood-protection programs. Through the Community Rating System, for instance, localities can earn premium discounts by enacting and enforcing building standards for flood hazards.

Perhaps the most effective tool is for communities to enact local comprehensive plans and zoning ordinances that manage new development in high-risk areas.

"There are many opportunities for communities to incorporate 'no-regrets' strategies," says Liz Fly, coastal climate specialist with the S.C. Sea Grant Extension Program and Carolinas Integrated Sciences and Assessments. (A "no-regrets policy" is cost-effective, reduces risks, and has benefits regardless of future climate.) "Local comprehensive plans can address today's problems such as

nuisance tidal flooding and, at the same time, address longer-term issues such as sea-level rise. These plans are typically reviewed every five-to-10 years, so they can be continually updated to changing conditions.”

But the NFIP has not worked out as intended, critics say. Many coastal localities continue to allow risky development in low-elevation zones with little or no consideration of rising sea level.

“Developers, builders, and state and local governments reap the rewards of coastal development but do not bear equivalent risk,” notes a 2014 report by the National Research Council (NRC). Instead, “the federal government has borne an increasing share of the costs of coastal disasters [with the result of] continued development and redevelopment in high-hazard areas.”

U.S. efforts to address disasters are primarily “reactive . . . with the vast majority of funding being provided only after disasters occur,” notes the NRC report. While localities generally decide where development is located, the federal government pays most costs of rebuilding after disasters.

Overall, the federal government allocates nearly 90% of its total disaster funding primarily to reconstructing damaged infrastructure—roads, beaches, seawalls, utilities—following disasters while only about 10% is allocated to improve resilience of infrastructure before disasters occur, according to the NRC report.

Meanwhile, population growth and public investments in high-risk flood zones continue unabated.

U.S. flood insurance has given developers and individuals an incentive to build in hazardous floodplains, according to Margaret Davidson, senior advisor for coastal inundation and resilience science and services at NOAA’s National Ocean Service.

“The United States is the only country with anything like our flood-insurance program,” says Davidson. “In the rest of the world, if you’re [unwise] enough to build in a flood-prone area,

that’s called an ‘assumption of risk,’ and nobody will bail you out.” Flood insurance, she says, has helped to make U.S. flood damage more frequent and expensive as more people build along the coast.

Influxes of coastal residents and visitors require new or improved roads, water and sewage systems, power stations, and utilities.

“We are continuing to lock in and exacerbate our risk,” says Davidson.

CONGRESS ACTS, STEPS BACK

In 2012, Congress reformed many aspects of the NFIP, but a public backlash soon forced Congress to alter the law’s direction.

Since its inception, the NFIP has offered sharply discounted policies—subsidized insurance—on grandfathered structures. These are buildings constructed in flood-hazard zones before 1968 when the program’s original rules were written.

After a series of devastating hurricanes and floods starting with Katrina in 2005, the NFIP fell into dire financial trouble. So, in 2012 the Biggert-Waters Act was passed to guide the program toward solvency and

improve its accuracy of flood mapping.

The law phased out grandfather subsidies for second homes, rental houses, and commercial properties that were not raised on pilings or new foundations. Single-family homes with subsidies would continue to be charged the lower rates until the structures were sold or if policies were allowed to lapse.

But these dramatic changes alarmed and confused many property owners who found that they could not sell their homes because the next owner’s insurance premiums would be so much higher, in some cases nearly tripling previous rates over time.

So Congress revised the law. In March, President Obama signed the Homeowner Flood Insurance Affordability Act of 2014, which repealed or modified some provisions in the 2012 act.

Under the new act, owners of grandfathered primary homes could pass on their subsidies to new owners. And homeowners whose policies had lapsed could regain subsidized rates under certain conditions. Congress added annual surcharges to all policyholders to make up for subsidized premiums on grandfathered structures.



EXACERBATED RISK. A new generation of federal flood-risk maps, to be released at the end of 2014 or early 2015, will likely increase flood-insurance premiums for some homes in low-elevation areas.

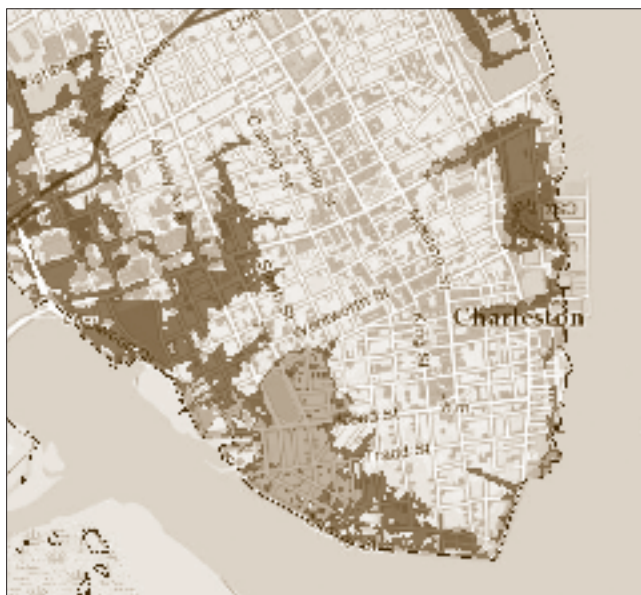
PHOTO/GRACE BEAHM

Lidar captures land elevations and features with far greater accuracy than ever before. As a result, scientists can visualize where sea-level rise and flooding impacts are likely to occur. FEMA will over time incorporate

"It's not that people are more flood-prone than they were before," says Marcy. "They still have the same flood risk. It's just that we can map the land elevation more accurately now."

FEMA's new flood-risk maps for coastal South Carolina are expected to be released at the end of 2014 or the beginning of 2015.

Potential Impact of Sea-Level Rise



Legend

■ 3 fl.

Service Layer Credits Sourced: Esri, TLR, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, AO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, Mapbox Inc., ©OpenStreetMap contributors, and the GIS User Community

MAP (LEFT)/DEPARTMENT OF GEOGRAPHY/UNIVERSITY OF ALABAMA
MAP (RIGHT)/SEAN BATH/S.C. SEA GRANT CONSORTIUM



RIISING WATER. Charleston will eventually need higher floodwalls, like this one at the Battery, as sea level continues to rise because of climate change.

PHOTO/GRACE BEAHM

PRESSURE'S BUILDING

To relieve nuisance flooding from low-elevation areas, the city of Charleston has been investing tens of millions of local, state, and federal dollars in new storm-drainage systems for the peninsula, including storage tunnels, pumping stations, and outlets.

The city's updated system, to be completed by 2020, has been designed to handle two additional feet of sea-level rise, says Laura Cabiness of Charleston's Department of Public Service. The system can be adapted later to handle another foot.

Charleston is forward-thinking in that respect, but some coastal communities want to do more. Consider a flood-protection plan for Hoboken, New Jersey, and adjacent Hudson River communities that were severely damaged during Hurricane Sandy.

Much of the Hoboken area,

originally settled on reclaimed salt marshes, is vulnerable to flash floods and storm surges. Under a new plan, the area would have a network of hard-and-soft infrastructure. Much of the waterfront would be shielded with hard barriers to protect against surges, but outside the high-risk waterfront would be modest shoreline berms, constructed wetlands, and more modest bays.

The Hoboken-area plan also calls for a "green circuit" of interconnected infrastructure to store excess rainwater until it evaporates, recharges groundwater, or is pumped out of the city.

Permeable paving, rain gardens, and bioswales would be added to some city streetscapes to absorb water. Along the Hoboken Light Rail, a linear series of pocket parks would serve as water-storage sites, and pumping stations would then discharge excess water into the Hudson River.

The Hoboken-area plan was one

of the six winners in a competition named Rebuild by Design organized by the U.S. Department of Housing and Urban Development (HUD).

Some 148 teams made up of experts in a variety of disciplines—architecture, urban design, engineering, ecology—proposed plans for redeveloping areas battered by Sandy. The Hoboken area received \$230 million from HUD to begin implementing its winning plan.

In New Orleans and New Jersey, reconstruction plans are reflecting the Dutch mantra: when building or rebuilding, always think about water.

So what's in store for Charleston? As sea level rises and downpours increase in intensity, will Charleston become a city of high fortified seawalls, canals, and extensive rain gardens?

Could the kayaker seen on Market Street in our time be a hint of the future? ♡

New tools spotlight state's sheltered shorelines

Think you've seen all of the South Carolina coast? Well, think again. There are nooks and crannies of shoreline that you'll probably never find. The state has 187 miles of sandy beachfronts but many thousands of miles of tidal sheltered shorelines.

To view them all, you'd need to travel along the state's many bays and sounds, trace coastal rivers and tributaries as far as saltwater will go, and follow scores of brackish creeks that wind through the archipelago from the Georgia state line past the sea islands named after kings, Johns and James, and then on to Bulls and Capers north of Charleston, and finally past the Grand Strand to Little River Inlet near the North Carolina state line.

Chester Jackson, a coastal geologist at Georgia Southern University, says that his new study offers evidence of more than 4,200 miles of estuarine shoreline just within the southern third of the South Carolina coast from the Savannah River to Edisto Island. This shoreline nearly equals the distance from Charleston to

Anchorage, Alaska.

Previous mapping showed less than 3,000 miles of estuarine coast, but new digital technologies allow scientists to see finer-grained and more accurate details of shoreline meanderings.

The entire estuarine shoreline of South Carolina is expected to be completely mapped and analyzed by the end of 2015 through a project supported by the U.S. Army Corps of Engineers and the S.C. Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management (SCDHEC-OCRM).

An April 2010 report by the S.C. Shoreline Change Advisory Committee encouraged SCDHEC-OCRM to develop baseline data for estuarine shorelines. Jackson's study is an important part of that ongoing effort.

One striking finding of the Jackson study is that almost two-thirds of estuarine shoreline in the study area experienced net erosion since the 1880s, with some shorelines eroding very quickly. Boating activities, dredging, and shoreline armoring drive some

erosion along the coast, but it seems clear that tidal-creek currents are become faster, affecting the location and intensity of erosion.

Sea-level rise is pushing more seawater through inlets into estuaries and filling creeks higher. Increased water volume and stronger currents in estuaries are creating new meandering patterns for creeks and shoreline erosion.

"Tidal creeks are taking on more water and speed," says Jackson, "so they are encroaching more and more" into salt marshes and upland shorelines. "The tidal streams are a lot more dynamic than we thought."

But it's difficult to determine how much erosion, velocity changes, and movement of tidal streams are directly attributed to sea-level rise. Storms and human activities are important contributors to estuarine changes, too.

If the state loses salt marshes to erosion, it will lose crucial storm-buffering habitat and important nursery habitat for fisheries.

Salt marshes can reduce the destructive energy of many coastal storms, according to a 2014 report by the National Research Council. But the marshes have to be relatively wide to provide a significant defense to upland shorelines where people have built homes and businesses.

The Charleston peninsula was once bordered by extensive salt marshes where the Battery stands today. Narrow, scattered fringes of salt marsh along the peninsula provide little storm protection. So, scientists say that it's important to protect South Carolina's 500,000 acres of remaining salt marsh.

As sea level rises, many salt marshes will migrate inland, but some will be blocked by hard erosion-control structures. Bulkheads are vertical wooden structures intended to control erosion along tidal creeks and bay-fronts. Revetments are large rocks or boulders that similarly hold the tidal



SHELTERED COAST. *The Charleston peninsula was once bordered by extensive salt marshes but nearly all were filled for development, including some areas now protected by the city's famous Battery.*

PHOTO/GRACE BEAHM

shoreline in place. Salt marshes, over time, will be squeezed between such hard structures and rising sea level until many marshes drown.

Since 2001, more than 1,300 property owners in South Carolina have acquired state permits to install hard, erosion-control structures along sheltered shorelines.

South Carolina officials consider issuing a permit for a bulkhead or other hard erosion-control structure along an estuarine (non-beachfront) shoreline when a waterway is eroding a property's high land. A landowner, however, would not receive a state permit if salt-marsh vegetation is migrating into an upland area and there is no evidence of erosion from a waterway.

But a South Carolina landowner with a migrating tidal shoreline can build a bulkhead farther upland on his property, outside of state jurisdiction, in anticipation of further erosion.

Where exactly are the most rapidly changing sheltered shorelines? The state has lacked coast-wide information about them. Soon, for the first time, the state will have the new digital map and statistical analysis of shoreline change.

"This mapping effort is particularly valuable because it significantly



LINE OF DEFENSE. Bulkheads, like this one, are the most common form of erosion-control device along South Carolina estuarine shorelines.

PHOTO/GRACE BEAHM

enhances our understanding of how the estuarine environment fluctuates and changes over time, and how human activities may influence that change," says Dan Burger, director of the Coastal Services Division of SCDHEC-OCRM.

"With these new maps and analytical tools," he says, "we'll be better able to identify where particularly vulnerable areas of erosion are. These

data may also help inform policies and interventions to guide development away from hazardous areas and to explore alternative shoreline stabilization techniques, such as living shorelines or oyster restoration, in suitable areas."

SCDHEC-OCRM is sharing information from the new maps with coastal municipalities to inform their hazard-planning efforts. ♡



Reading and Websites



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NEWS & NOTES

Taylor elected Consortium board chair

Col. Alvin A. Taylor, director of S.C. Department of Natural Resources (SCDNR), has been elected as chair of S.C. Sea Grant Consortium's Board of Directors. Taylor will begin his one-year term on January 1, 2015.

"I look forward to my term as chairman of the S.C. Sea Grant Consortium," said Taylor. "The Consortium's work is important to our state, and it will be a pleasure to work with such an impressive board and outstanding staff."



Col. Alvin A. Taylor
PHOTO/S.C. DEPARTMENT
OF NATURAL RESOURCES

Taylor serves as the chief administrator for natural resources in the state with a staff of over 900 in numerous locations across South Carolina.

He graduated from Clemson University in 1976 with a B.S. in zoology. He completed training at the U.S. Coast Guard Law Enforcement Training Center in Yorktown, Virginia, in 1976, and graduated from the S.C. Criminal Justice Academy in 1977.

He began his career with the agency that year and progressed through the ranks serving as an officer, private first class, sergeant, lieutenant, captain, major, and colonel, the agency's law-enforcement chief. He is a certified SCUBA diver and for several

years supervised the SCDNR Aquatic Investigations and Recovery Unit dive team.

"I very much look forward to working with Col. Taylor this coming year as chair of the Consortium's Board of Directors," said Rick DeVoe, executive director of the S.C. Sea Grant Consortium. "His leadership and many years of experience working on natural resource and economic development issues in the state will be invaluable to the Consortium's work in meeting the information needs of our diverse constituencies."

The Consortium's Board of Directors is composed of the chief executive officers of its member institutions. Currently serving on the board are: Dr. David A. DeCenzo, current board chair and president of Coastal Carolina University; Dr. James B. Clements, president of Clemson University; Glenn F. McConnell, president of College of Charleston; Dr. David J. Cole, president of Medical University of South Carolina; Col. Alvin A. Taylor, executive director of S.C. Department of Natural Resources; Thomas J. Elzey, president of S.C. State University; Lt. General John W. Rosa, president of The Citadel; and Dr. Harris Pastides, president of University of South Carolina. ♡

LID manual now available

A new manual, *Low Impact Development in Coastal South Carolina: A Planning and Design Guide*, has recently been published. The S.C. Sea Grant Consortium Extension program, in partnership with the ACE Basin



and North Inlet-Winyah Bay National Estuarine Research Reserves (NERR) and the Center for Watershed Protection, developed the guide to assist coastal decision-makers with how to implement low impact development (LID) techniques in order to mitigate stormwater impacts. The project team organized three stakeholder workshops, two research "roundtables," and contributed their own technical knowledge of LID practices to develop this comprehensive publication. The guide was made possible by a NERRS Science Collaborative grant.

The guide is specific to coastal South Carolina and contains five chapters which cover the following topics: Introduction to LID in Coastal S.C.; Strategies for Local Governments; Conservation Principles and Neighborhood Site Design; Stormwater Best Management Practices (BMPs); and Local Case Studies. Also included are eight appendices, with information ranging from infiltration testing and soil compost amendment

NEWS & NOTES

to coordinating erosion control and stormwater statutes and regulations. An extensive section of maintenance checklists is also provided, as well as an online compliance calculator tool useful for engineers to evaluate and predict stormwater runoff, determine the most effective BMPs for a given site, and how to decide if additional measures are needed to provide channel and flood protection for major rainfall events.

Visit www.northinlet.sc.edu/LID to download the entire guide or individual chapters, as well as the compliance calculator tool. Contact April Turner, coastal communities extension specialist, at (843) 953-2078 or april.turner@scseagrant.org to receive a hard copy of the guide. ✓

Consortium wins stewardship grants

The S.C. Sea Grant Consortium has been awarded two grants to help improve the stewardship of coastal resources.

The Environmental Protection Agency's Office of Environmental Education awarded a \$78,564 grant to the Consortium to expand its successful From Seeds to Shoreline program (S2S), a student-driven salt-marsh restoration education effort.

The Consortium, in partnership with the S.C. Department of Natural Resources, will expand the S2S program throughout South Carolina by training staff at informal science education centers to work closely with schools participating in the program in their area.

Educational resources on tidal



PHOTO/SUSAN FERRIS HILL/S.C. SEA GRANT CONSORTIUM

creek-salt marsh ecosystems will be developed to supplement the program's content. The Consortium will create state-based "communities of practice," including formal and informal educators, to help develop and test educational resources and to implement the program.

Finally, the Consortium will expand its S2S program to additional southeastern states (North Carolina and Georgia) working closely with each state's Sea Grant program and National Estuarine Research Reserves to train teachers and staff at science education hubs throughout the region.

In addition, a stewardship grant of \$143,344 has been awarded to the Consortium by the National Oceanic and Atmospheric Administration National Marine Fisheries Service. This grant is intended to both remove derelict vessels from the Charleston Harbor watershed and engage community organizations and volunteers in the identification and removal of large-scale marine debris in

Charleston County.

The Consortium, in partnership with the S.C. Department of Health and Environmental Control – Office of Ocean and Coastal Resource Management, will help organize Clean Marine events scheduled for spring 2015, fall 2015, and spring 2016. The Clean Marine events will provide county-wide training and other activities related to marine debris before each event.

An estimated 15 tons of marine debris (primarily unwanted fishing gear) will be collected and disposed of during the events, which will be open to recreational and commercial fishers and the public.

Also, as part of the overall grant, 14 derelict vessels weighing 22-26 tons will be removed from the Charleston Harbor watershed, improving both the safety of navigable waterways and the health of essential fish habitat.

For more information, contact Elizabeth Vernon Bell at ev.bell@scseagrant.org or (843) 953-2085. ✓



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EBBS & FLOWS

95th AMS Annual Meeting

Phoenix, Arizona
January 4-8, 2015

The theme of the American Meteorological Association's Annual Meeting is "Fulfilling the Vision of Weather, Water, and Climate Information for Every Need, Time, and Place." The conference will explore how our community is turning this vision into reality. It will focus on the scientific, technical, and professional advancements required to develop and deliver widespread, highly customized weather, water, and climate information. For more information about the meeting, contact meetings@ametsoc.org.

5th Interagency Conference on Research in the Watersheds

Charleston, South Carolina
March 2-5, 2015

This conference brings together watershed scientists, stakeholders, and managers to share scientific advances and management strategies to sustain the country's water resources. We will take a national perspective on watershed science and management, while highlighting the coastal landscape, which is represented by the location of the conference in the South Carolina lowcountry. Contact Carl Trettin of the U.S. Forest Service at (843) 336-5602 or ctrettin@fs.fed.us for more information.

Coastal Geotools

N. Charleston, South Carolina
March 30-April 2, 2015

Coastal GeoTools, held every two years, focuses on geospatial data, tools, technology, and information for professionals involved in developing and applying geospatial technology for management of coastal resources. This year's conference is sponsored by the Association of State Floodplain Managers. Coastal professionals from many different sectors find the networking opportunities of the conference unique and important for furthering goals of their organizations. For more information, contact info@coastalgeotools.org.

Subscriptions are free upon request by contacting: Annette.Dunmeyer@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at www.scseagrant.org/education.